CONCRETE DAM WITH CONFINED GROUNDWATER FLOW

This document verifies that groundwater flow principles are correctly implemented in PLAXIS. Three concrete dams with different underground configurations are considered, i.e. one without impermeable screen, one with impermeable screen at the upstream side and one with impermeable screen at the downstream side.

Used version:

- PLAXIS 2D - Version 2018.0
- PLAXIS 3D - Version 2018.0

Geometry: The dams are founded on an impervious isotropic soil (Figure 1). Seepage flow is modelled in PLAXIS 2D and PLAXIS 3D for all three cases and the results are compared to the ones obtained from the flow net method (Lambe & Whitman, 1979). The analytically obtained streamlines and equipotentials are presented in Figures 1 to 3. Total discharge under the dams and water pressure head at point A (toe of the dam, refer to Figures 1 and 3) are selected to be the validation criteria.

The concrete dams are simulated by non-porous material and their embedded depth equals 1.5 *m*. In PLAXIS 2D, two geometry lines with positive (or negative) interface are used to model the impermeable screens at the upstream and downstream edge of the Dams II and III correspondingly. They are extended to a depth equal to 4.5 *m* below the bottom part of the dam (Figures 2 and 3). The resulting geometry is illustrated in Figure 4.

In PLAXIS 3D, the concrete dams have the same geometry as above. Their width in y-direction equals 1 *m* (plane strain condition). The impermeable screens are modelled with two surfaces, in which a positive (or negative) interface is assigned. The resulting geometry is presented in Figure 5.

The groundwater flow boundary conditions for the selected dam configurations are given in Table 1.

Table 1 Groundwater flow boundary conditions

Dam	Bottom	Top	Upstream & Downstream	Sides
I	Closed	Seepage	Seepage	Closed
II	Closed	Seepage	Seepage	Closed
III	Closed	Seepage	Seepage	Closed

Materials: The adopted material parameters are:

Soil: Linear elastic Drained $E' = 1$ kN/m^2 $k = 5.0 \times 10^{-6}$ m/sec

Dam: Linear elastic Non-porous $E = 1$ kN/m^2

Meshing: In both PLAXIS 2D and PLAXIS 3D models, the *Fine* option is selected for the *Element distribution*. The two geometry lines/surfaces which represent the impermeable screens are refined with a *Coarseness factor* of 0.1. To reduce the number of generated finite elements a *Coarseness factor* equal to 1.0 is used everywhere else. The resulting mesh is shown in Figure 6 and Figure 7.

Calculations: The calculations are performed using the *Flow only* mode with *Steady state groundwater flow* as the *Pore pressure calculation type*. The bottom groundwater flow boundary is set to *Closed* in both PLAXIS 2D and PLAXIS 3D. In addition, both groundwater flow boundaries in the y-direction are set to *Closed* in PLAXIS 3D. The

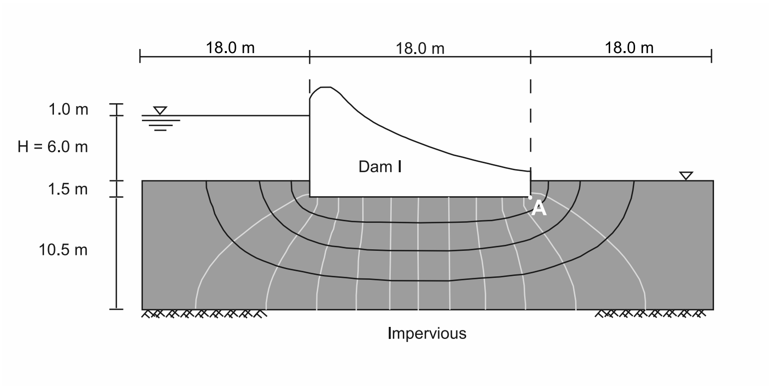

Figure 1 Geometry of Dam I without impermeable screen. Streamlines and equipotentials are illustrated as well (Lambe & Whitman, 1979)

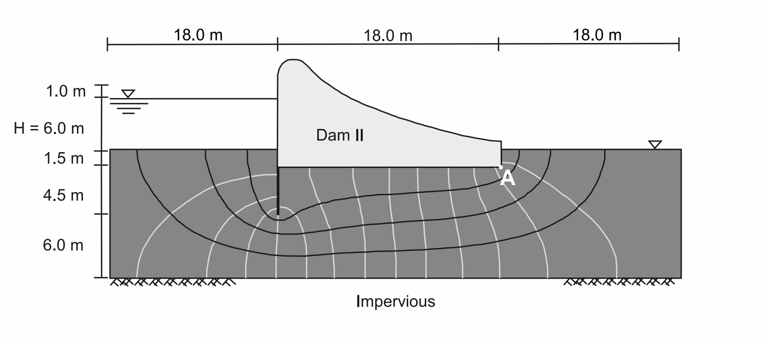

Figure 2 Geometry of Dam II with an impermeable screen at the upstream side. Streamlines and equipotentials are illustrated as well (Lambe & Whitman, 1979)

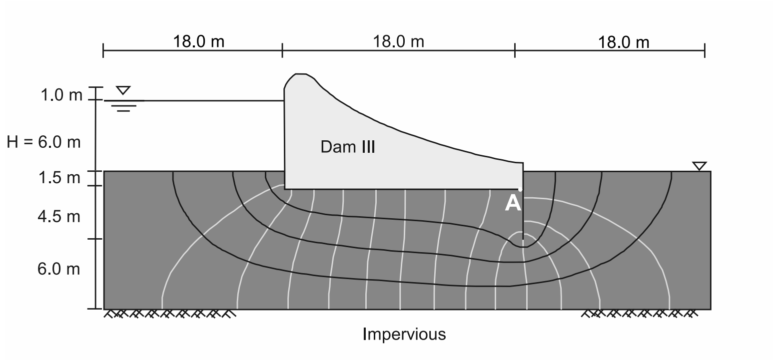

Figure 3 Geometry of Dam III with an impermeable screen at the downstream side. Streamlines and equipotentials are illustrated as well (Lambe & Whitman, 1979)

tolerated error is selected equal to 5.0×10^{-6}.

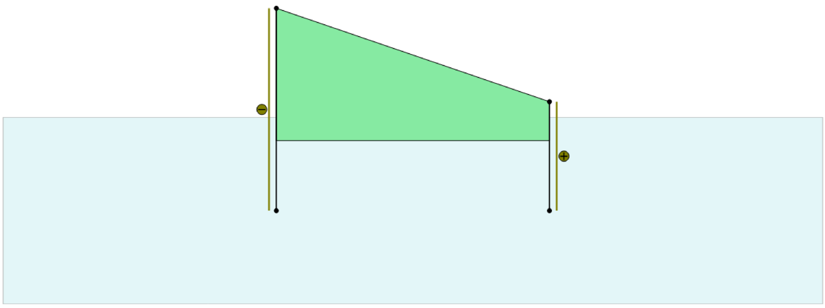

Figure 4 Model geometry (PLAXIS 2D)

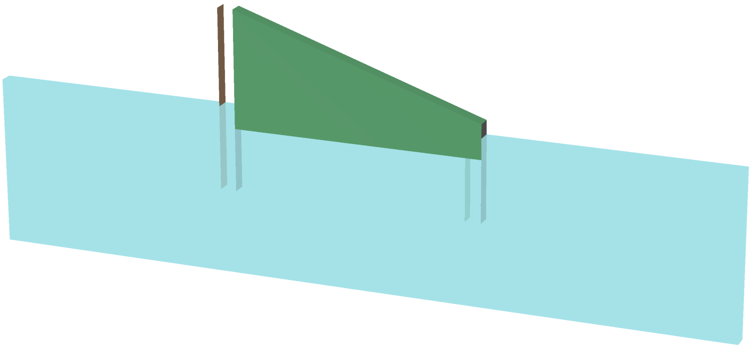

Figure 5 Model geometry (PLAXIS 3D)

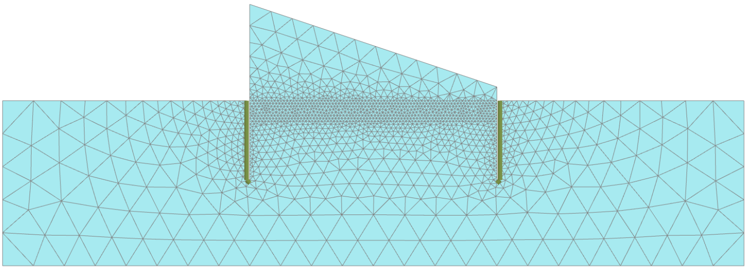

Figure 6 Generated mesh (PLAXIS 2D)

Output: The potential heads (equipotentials) calculated in PLAXIS 2D and PLAXIS 3D for all three cases are presented in Figures 8 to 10 and Figures 11 to 13 respectively. In order to obtain the PLAXIS 3D results, a vertical cross section at y = 0.5 m is used. It can be seen that the results are in good agreement with the theoretical ones, presented in Figures 1 to 3.

Verification: Comparison of the results obtained from PLAXIS and the flow net method is presented in Table 2 and Table 3. It is concluded that PLAXIS results are in good agreement with the analytical solution.

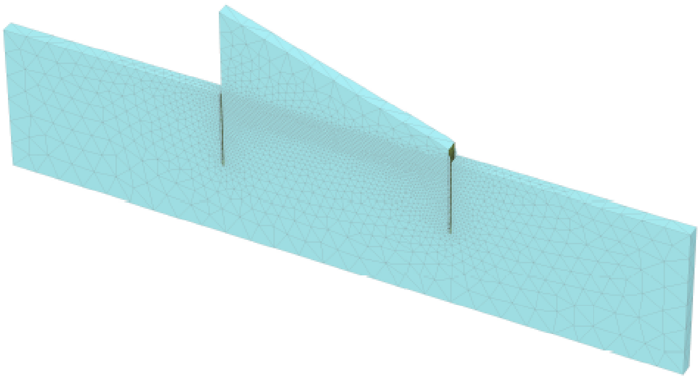

Figure 7 Generated mesh (PLAXIS 3D)

Hint: In Dam III, the point A is located at the upstream side of the impermeable screen.

» The values of the uplift water pressure head presented in Table 3 are calculated by considering the pore water pressure p_{water} at steady-state conditions, divided by the unit weight of water (by default in PLAXIS: 10.00 kN/m^3).

Table 2 Comparison between total discharge under the dams obtained from PLAXIS and the flow net method

Dam	Total discharge under dam (m^3/sec/m)			Error (%)	
	Lambe and Whitman	PLAXIS 2D	PLAXIS 3D	PLAXIS 2D	PLAXIS 3D
I	$1.029 \cdot 10^{-5}$	$1.030 \cdot 10^{-5}$	$1.029 \cdot 10^{-5}$	0.1	0.0
II	$8.840 \cdot 10^{-6}$	$8.681 \cdot 10^{-6}$	$8.681 \cdot 10^{-6}$	1.8	1.8
III	$8.840 \cdot 10^{-6}$	$8.679 \cdot 10^{-6}$	$8.681 \cdot 10^{-6}$	1.8	1.8

Table 3 Comparison between uplift water pressure head results (point A) obtained from PLAXIS and the flow net method

Dam	Uplift water pressure head at point A (m)			Error (%)	
	Lambe and Whitman	PLAXIS 2D	PLAXIS 3D	PLAXIS 2D	PLAXIS 3D
I	2.25	2.18	2.19	2.9	2.9
II	2.13	2.08	2.08	2.5	2.5
III	3.87	4.01	4.00	3.5	3.5

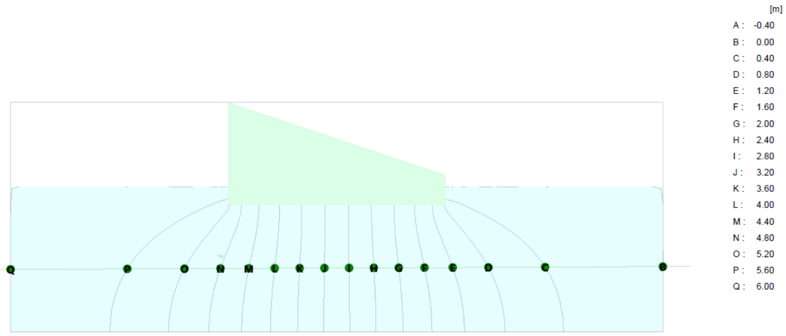

Figure 8 Potential heads under Dam I (PLAXIS 2D)

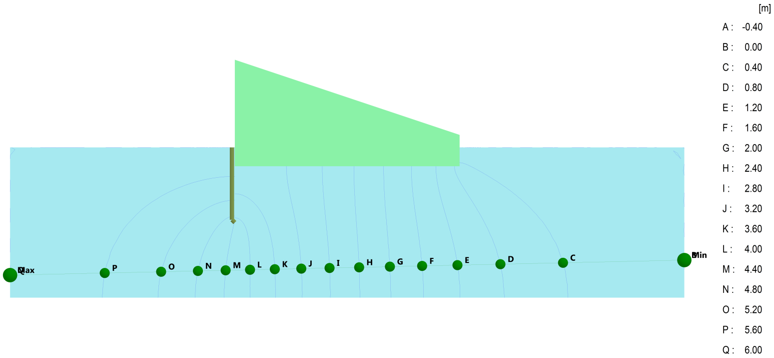

Figure 9 Potential heads under Dam II (PLAXIS 2D)

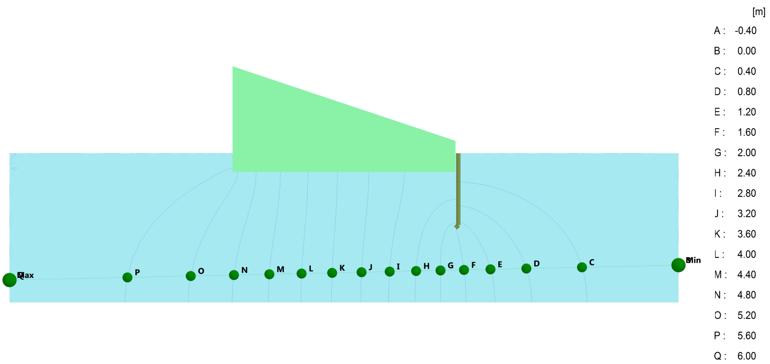

Figure 10 Potential heads under Dam III (PLAXIS 2D)

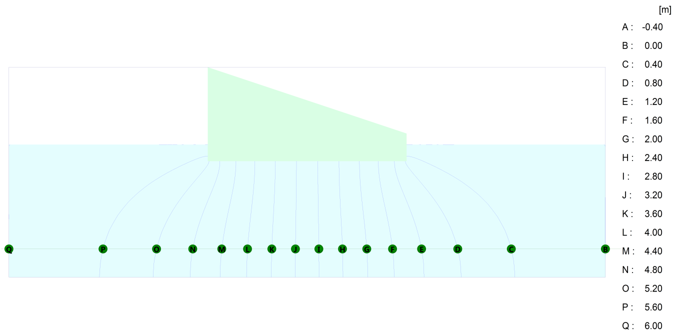

Figure 11 Potential heads under Dam I (PLAXIS 3D, vertical cross section at y = 0.5 m)

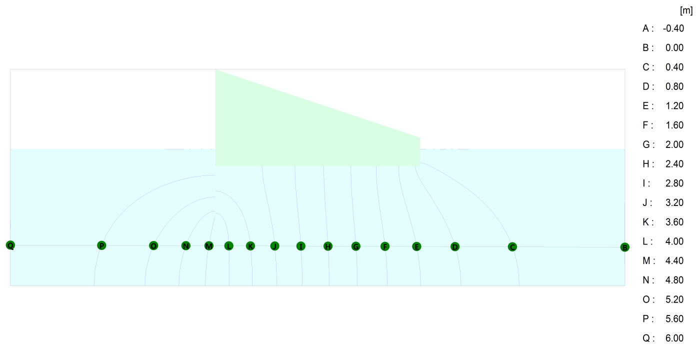

Figure 12 Potential heads under Dam II (PLAXIS 3D, vertical cross section at y = 0.5 m)

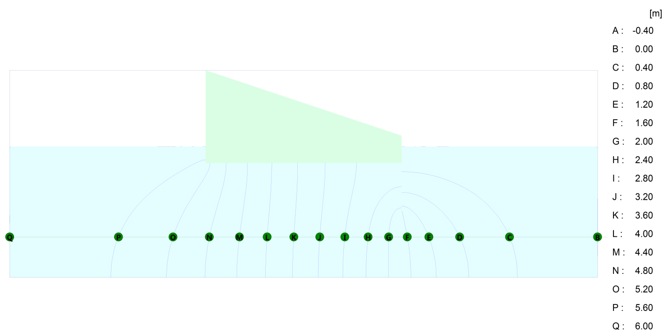

Figure 13 Potential heads under Dam III (PLAXIS 3D, vertical cross section at y = 0.5 m)

REFERENCES

[1] Lambe, T.W., Whitman, R.V. (1979). Soil Mechanics. John Wiley and Sons.